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ABSTRACT

Results from seasonal (4/5 month) 9-member ensemble integrations of the UK Meteorological Office Unified Model are analysed for two periods with two objectives: first, to examine the behaviour of an ensemble over Brazil for the El Niño period of November 1986 to February 1987 and, second, to compare results for two years of contrasting rainfall in the Nordeste region of Brazil (January to May 1993 and 1994). In both cases convective rainfall simulations from the models are contrasted with observed data. For the 1986/87 case average observed rainfall anomalies over five areas of South America are compared with percentages of normal rainfall (calculated from the model climatology) for the ensemble members and the ensemble mean. In three areas ensemble mean rainfall anomalies compare closely with observed values, but the model underestimates anomalies in the other two areas although in a manner consistent with the occurrence of an El Niño event. Frequency distribution analyses show that rainfall from individual ensemble members converge to similar values in all areas in some months, but that convergence is generally better in areas representing the more southerly and westerly parts of Brazil. The variability of predictions between members demonstrates the importance of using an ensemble, particularly for areas along the northern Atlantic coast; simulations appear more sensitive to SST changes in the tropical and coastal, rather than the continental, areas. Differences in precipitation between 1993 and 1994, years of strongly contrasting rainfall, are well simulated by the model. The larger differences in rainfall occurred in the Inter-Tropical Convergence Zone (ITCZ) and the South Atlantic Convergence Zone (SACZ). Wind analyses are also consistent with the increased precipitation of 1994. Model simulations of seasonal-average rainfall over the Nordeste (for March to May) are consistent with observations in 1993 and 1994.

1. INTRODUCTION

The U.K. Meteorological Office Unified Model is being used to make an extensive series of experimental monthly and seasonal predictions. Both statistical and General Circulation Models have indicated that rainfall in the Nordeste region of Brazil has a high degree of predictability; for example, simulated rainfall totals by Hastenrath and Greischar (1993), Ward and Folland (1991), Moura and Herdies (1994) and Richardson and Robertson (1994) have agreed well with observed precipitation. In this report, experimental Unified Model hindcasts for South America are analysed; version 3.2 of the model was used at climate resolution (2.5° by 3.75°). The model integrations were made using the portable version of the Unified Model on DEC Alpha workstations. Two approaches are made, one examining the behaviour of model results associated with different initial conditions using ensemble techniques, and a second analysing differences between simulations from two years of opposing observed precipitation anomalies in the Nordeste. Results presented in this Report were analysed during a visit to the Meteorological Office of Iracema Cavalcanti (CPTEC/INPE) under the Visiting Scientist Programme.

2. PERFORMANCE DURING THE 1986/87 EL NIÑO

The ensemble study was performed with 7 members, using initial conditions every 24 hours from 0000Z 24 to 30 October 1986. A major El Niño peaked in January 1987 - El Niño's are normally associated with dry conditions over the Nordeste region. Simulations were carried through November, December, January and February, using as boundary conditions observed monthly Sea Surface Temperatures (SST's). A further ensemble, using climatological monthly SST's, from initial conditions of 0000Z 24 to 28 October 1986 (5 members) was obtained as a control. Percentages of normal precipitation were calculated for both model results and observed values.

Model grid-point convective precipitation averages were calculated for 5 areas over South America (Fig. 1): Area I: 0°-10°S, 50°W-35°W (Northeast, which includes the Nordeste); Area II: 10°S-20°S, 50°W-35°W (Central East); Area III: 20°S-35°S, 60°W-35°W (South); Area IV: 5°N-10°S, 75°W-50°W (Northwest); and Area V: 10°S-20°S, 75°W-50°W (Central West). Convective rainfall totals should provide a good approximation to the observed precipitation in the tropical and subtropical regions of Brazil at this time of the year, when even frontal systems produce convective activity while passing over the continent. Area averages (in terms of percentages of normals as computed from the control runs created using climatological SST's) were compared between members in order to examine the variability using different initial conditions. They were also compared with observed rainfall percentages calculated from averages over 1961 to 1990 data for the same areas. Observed rainfall data were obtained from Instituto Nacional de Meteorologia (INMET), Brazil.

Monthly percentage anomalies for the 5 members for which control runs are available, for the ensemble average and for observed values in each area, together with seasonal totals, are shown in Figure 2. The percentage of normal precipitation was underestimated by almost all members of the ensemble in the Northeast (Area I) from November to February. There are large differences between predictions for individual members; nevertheless the model's response to the SST of an El Niño year is indeed below-normal precipitation in this region. However observed rainfall was above or near-normal, an outcome likely to have been associated with occurrences either of the high-level cyclonic vortices which can occur in January and February or with the passage of frontal zones near the coast. Over the Central East region the ensemble mean was closest to observed values in November and December but rainfall was overestimated in January and February by the majority of members. Actual precipitation was below normal during the whole period except in December, suggesting that the South Atlantic Convergence Zone (SACZ), which affects this area, was weaker than usual. Ensemble mean anomalies were similar to observed values for the South Region in November and January, but in December and February some individual members provided better estimates of observed values than did the ensemble mean. Observed precipitation was close to normal except in December, the positive anomaly being captured by one of the members. In the Northwest region, which includes Amazonia, observed values were generally similar to those of the ensemble mean, with the exception of November, although the error is only of order 25% even if the sign of the ensemble mean anomaly differs from

that of the observed anomaly. From December to February precipitation was below normal, consistent with an El Niño year. Simulations from the ensemble for the Central West region are also acceptable.

Closest agreements between ensemble mean and observed seasonal anomalies (December to February) occur over the South, Northwest and Central West. There is less agreement for the other two regions, but the ensemble manages to capture the observations within its range (or nearly so) in both cases.

Analyses were also made using frequency distribution histograms for each month for individual members (Fig. 3). These histograms show how many members have predicted rainfall lying within a specific range of values using both observed and climatological SST's. Results for the Central West, in the interior of the continent, and for the South, a subtropical region, are similar regardless of SST's. Further, there is limited variability between members, perhaps suggesting that initial conditions have relatively minimal effects on predicted precipitation over the two areas, at least in this one case. There is a rather larger impact of observed SST's in the other three (tropical) regions, two of which border the ocean, with distributions somewhat different between SST sets although spread is generally relatively limited for each specific SST set.

In summary, the ensemble, at least in this single case, appears to be able to provide realistic predictions over much of Brazil during an El Niño event. Simulations appear more variable and more sensitive to SST's in the tropical and coastal, rather than the continental, areas.

3. CONTRASTS BETWEEN 1993 AND 1994

In this section simulations for January to May of both 1993 and 1994, using initial conditions of 1 January 1993 and 1994 respectively with observed monthly SST's, are discussed. The effect of using persisted instead of observed SST anomalies is assessed using initial conditions of 1 January 1994, with December anomalies persisted through the integrations.

a) Precipitation

The Nordeste had a severe drought in 1993, contrasted with a wet 1994 season. Table I shows the observed precipitation as a percentage of normal in the Nordeste. In order to compare results with observed precipitation anomalies, 1993 and 1994 (January to May) simulated averages for the Nordeste are shown in Table II. Observed and model results for the seasonal March to May totals compare well in general. The model results also show a decrease in precipitation from January to May in both years, as was observed.

	1993	1994
JANUARY	84.7	371.5
FEBRUARY	103.7	128.6
MARCH	66.2	96.9
APRIL	71.5	120.0
MAY	74.6	126.7
JANUARY/FEBRUARY	94.2	250.1
MARCH - MAY	70.8	114.6

Table I - Percentage of observed precipitation in the Nordeste

Differences between simulated rainfalls for 1994 and 1993 for each month have been created in order to examine the behaviour in these two years. Then, positive values for the difference field of convective rain will indicate increased precipitation in 1994 compared to 1993. In all months from January to May, for both observed and persisted SST's, the model predicts more precipitation over the Nordeste in 1994 than 1993, in agreement with the observed behaviour of the rainfall (Figs 4 to 13). However, there are some differences between the simulations with observed and persisted SST's, related to the areas of relatively heavy precipitation and to the Inter-Tropical Convergence Zone (ITCZ) position.

	1993		1994		
	OBSERVED	MODEL (OBS SST)	OBSERVED	MODEL (OBS SST)	MODEL (PER SST)
JANUARY	93.5	182.9	410.2	280.6	192.8
FEBRUARY	154.8	181.6	192.1	258.5	236.4
MARCH	151.4	168.6	221.8	239.4	226.8
APRIL	132.9	157.2	223.1	164.7	190.3
MAY	85.7	79.9	145.6	157.9	153.3
MARCH - MAY	123.3	135.2	196.8	187.3	199.9

Table II - Observed precipitation and convective rainfall from the ensemble mean (mm)

There were substantial simulated rainfall differences between January 1993 and January 1994 in the ITCZ and SACZ regions over the Atlantic Ocean and in the ITCZ and South Pacific Convergence Zone (SPCZ) regions over the Pacific Ocean. The main differences between simulated rainfall using observed SST's (Fig. 4) and persisted SST anomalies (Fig. 5) are found in the position of Atlantic ITCZ, which, using observed SST's, is displaced southward and linked to the SACZ in 1994, thus affecting the precipitation over the Nordeste. In February similar differences are simulated over the Nordeste for both observed and persisted SST's, with increased precipitation in the ITCZ and SACZ areas (Figs 6 and 7). Part of the southeast of Brazil is also affected by increased precipitation.

In March differences between observed and persisted SST simulated rainfall totals are larger than in January and February (Figs 8 and 9). In the simulations with persisted SST's positive rainfall anomalies on the ITCZ lie south of the Equator and affect the north and east parts of Nordeste; with observed SST's the ITCZ anomalies extend north of the Equator and are displaced relatively westwards but still affect the northern part of the Nordeste. There are two bands of positive convective rain differences over the North and South Pacific Ocean, representing a double and stronger ITCZ in 1994, in both simulations.

The main anomalies in April are related to an extension of the Atlantic ITCZ into the interior of South America, which affects only the north (observed SST's) and east (persisted SST's) part of the Nordeste (Figs 10 and 11). Precipitation anomalies over the south of Nordeste are linked to those in the SACZ. The two sets of results show the same behaviour in the North Pacific Ocean, but there are differences over the South Pacific related to the ITCZ and SPCZ regions.

In May the observed SST simulations have increased precipitation in an extended band affecting the whole coast of northern South America through to the Atlantic ITCZ (Fig. 12), while the persisted-anomaly simulation has increased precipitation in the north and east part of Nordeste and there is a tilting in the ITCZ anomalies from northeast of Brazil to the eastern tropical North Atlantic near Africa (Fig. 13). Over the North Pacific Ocean anomalies are broken up in both results but over the South Pacific Ocean anomalies in the ITCZ and SPCZ remain essentially similar.

Increased convective precipitation in 1994 as opposed to 1993 over other parts of South America is mainly simulated in March around Uruguay at about 30° to 35°S. A limited increase also occurs in April in this same area. These results might be affected by use of simulated convective rain only.

Differences between 1993 and 1994 observed precipitation fields over Brazil are shown in Figures 14 to 18 (cf. Figs 4 to 13). The increased precipitation in 1994 appears to have been well simulated, particularly in the ITCZ and SACZ regions, affecting the far north and south of Nordeste.

b) Wind Field

There was an increase in the simulated 200 hPa westerly flow in the subtropical region over South America, and a reduction over south of South America, in January and February of 1994 when compared to 1993. In March the situation is reversed, with an increase of westerlies over south of South America and a reduction over the subtropical area. Thus there was an opposing shift in the latitude of the zonal wind maximum between 1993 and 1994; in 1993 the latitude of the maximum wind shifted northward between January and March, but in 1994 the shift was southward. Figure 19 illustrates this difference in the zonal wind field for January and March; the fields are similar for both observed SST's and persisted SST anomalies. Examples of zonal wind differences at 850 hPa in January and March are shown in Figure 20. There was an increase in easterlies over the tropical North Atlantic and a reduction of easterlies over the tropical South Atlantic in January. In March there was a reduction of easterlies over equator. This change in winds has a major implication for the precipitation over the Nordeste, because it indicates a southward displacement of the ITCZ in 1994, implying greater Nordeste rainfall, compared to 1993.

The meridional wind difference fields are shown in Figures 21 at 200 hPa and Figure 22 at 850 hPa, for January and March. At 200 hPa the sign changes from January to March over northeast and southeast Brazil. In January these differences indicate strong divergence, and in March relatively weak convergence, over the Nordeste in 1994 compared to 1993. Over the Nordeste, at 850 hPa, there was an increase in southward winds in 1994, a change consistent with the southward displacement of the ITCZ. In general these simulated wind changes are consistent with observed changes between wet and dry years over the Nordeste.

5 CONCLUSIONS

The U.K. Meteorological Office Unified Model was used to produce ensembles to assess the model's response over South America to anomalous SST's and to compare rainfall simulations for two contrasting years over the Nordeste of Brazil. The results are relatively more sensitive to the initial conditions and to boundary conditions in the tropical regions close to the ocean than elsewhere in Brazil. The wind field shows the same large scale features for all members over South America. There was a large variability in consistency between observations and the model results, i.e. in some months the results agreed well in some areas, but not for all months and all areas. An increase in precipitation in 1994 compared to 1993 was well identified by the model for both observed SST's and persisted SST anomalies. Differences between the years were related to the position and extension of the Atlantic ITCZ and they are larger from March to May. In this experiment the model appeared to provide better simulations for the Nordeste in March, April and May (1993 and 1994), the main Nordeste rainfall season, than in November to February (1986/87). Additional analyses and other experiments are needed to provide an improved view of the comparison between model and observed results.

ACKNOWLEDGEMENTS

We are grateful to Tim Legg for helping with SAS graphic software and to Dirceu L. Herdies for the observed rainfall data.

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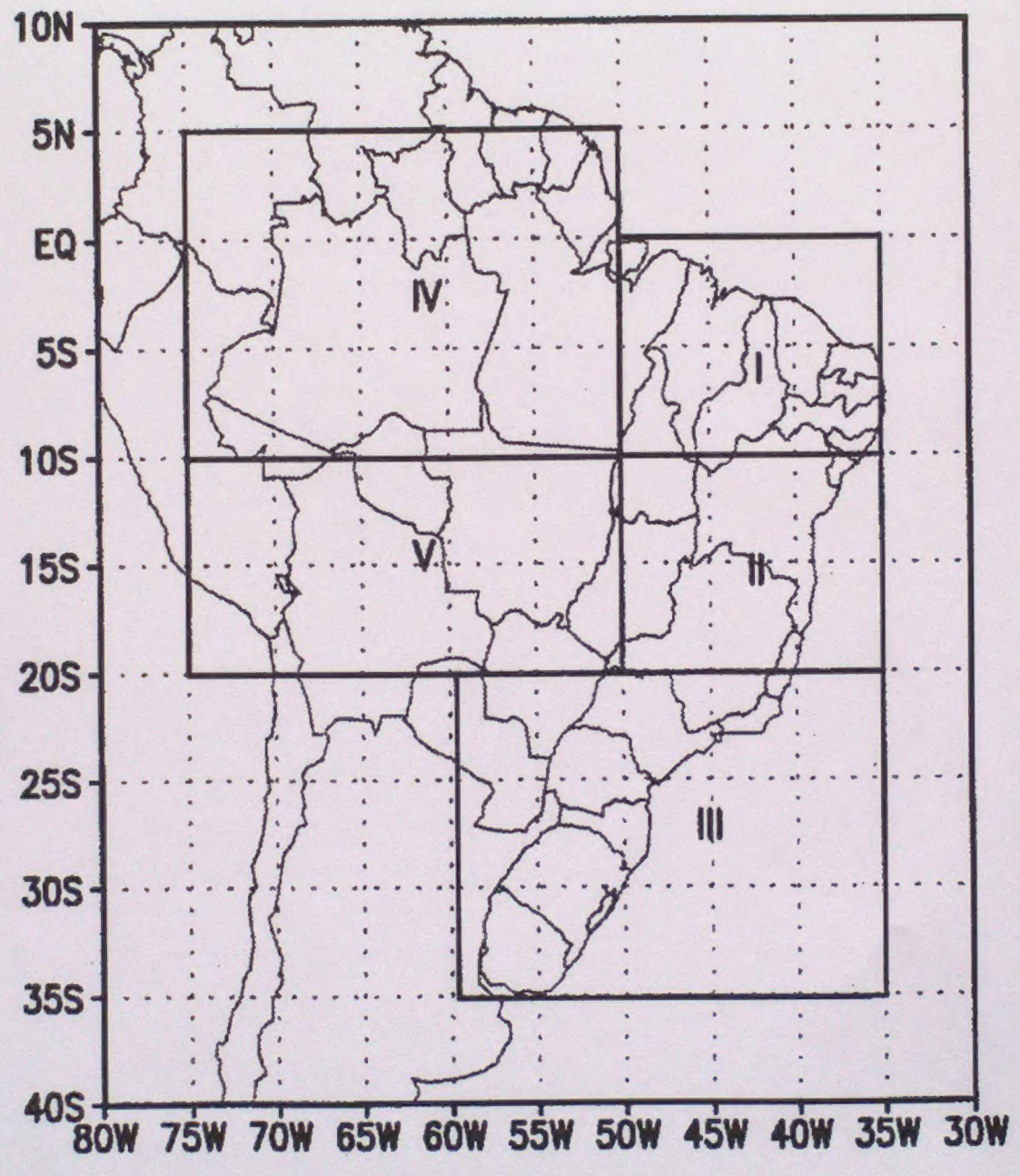


Fig.1- Areas I (Northeast), II (Central East), III (South), IV(Northwest), V(Central West).

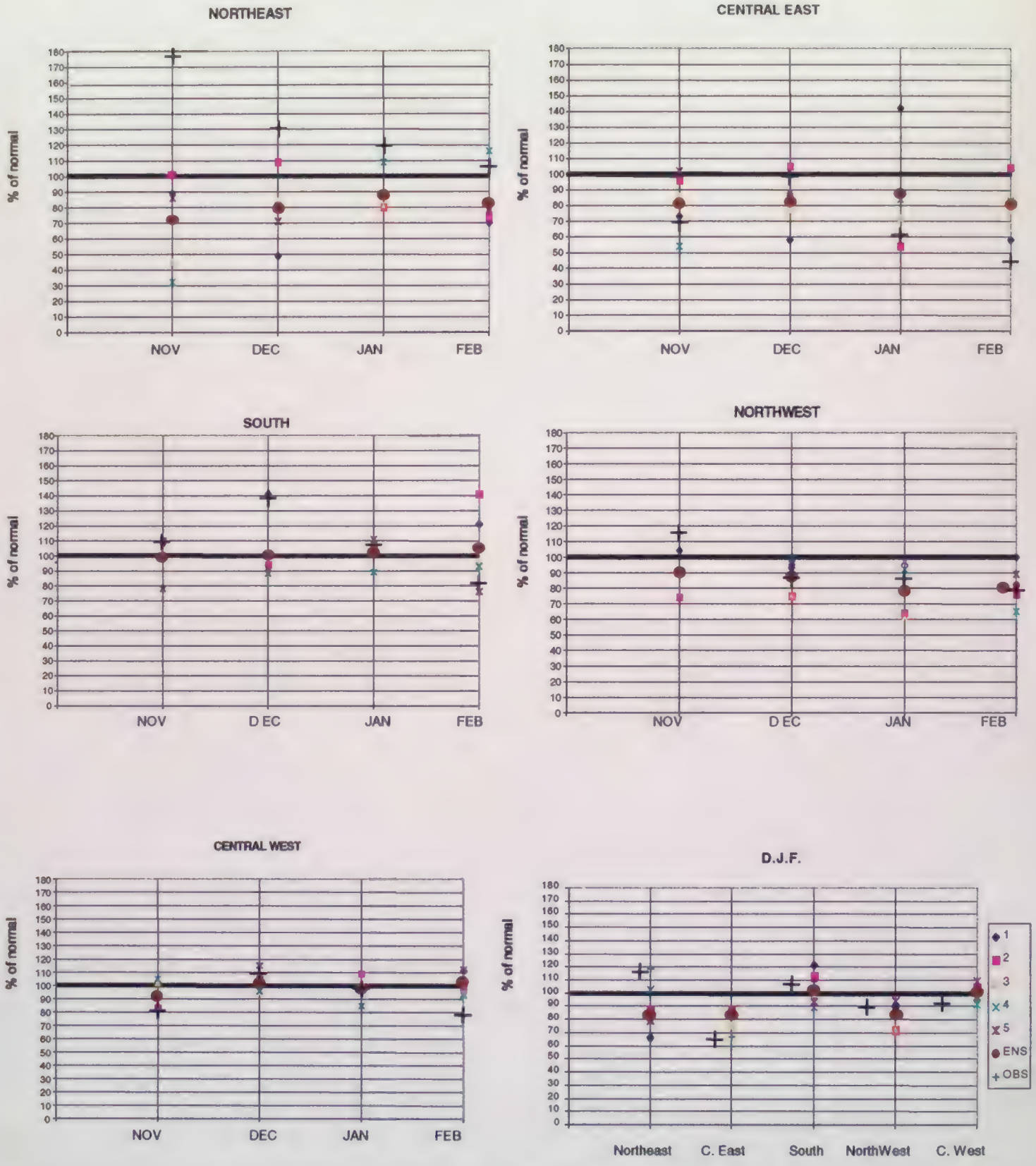


Fig. 2- Percentage of normal precipitation of 5 members, represented by the symbols 1 to 5. ENS indicates the ensemble average and OBS the observed percentage of normal precipitation. D.J.F. is the average of December, January and February for the 5 areas.

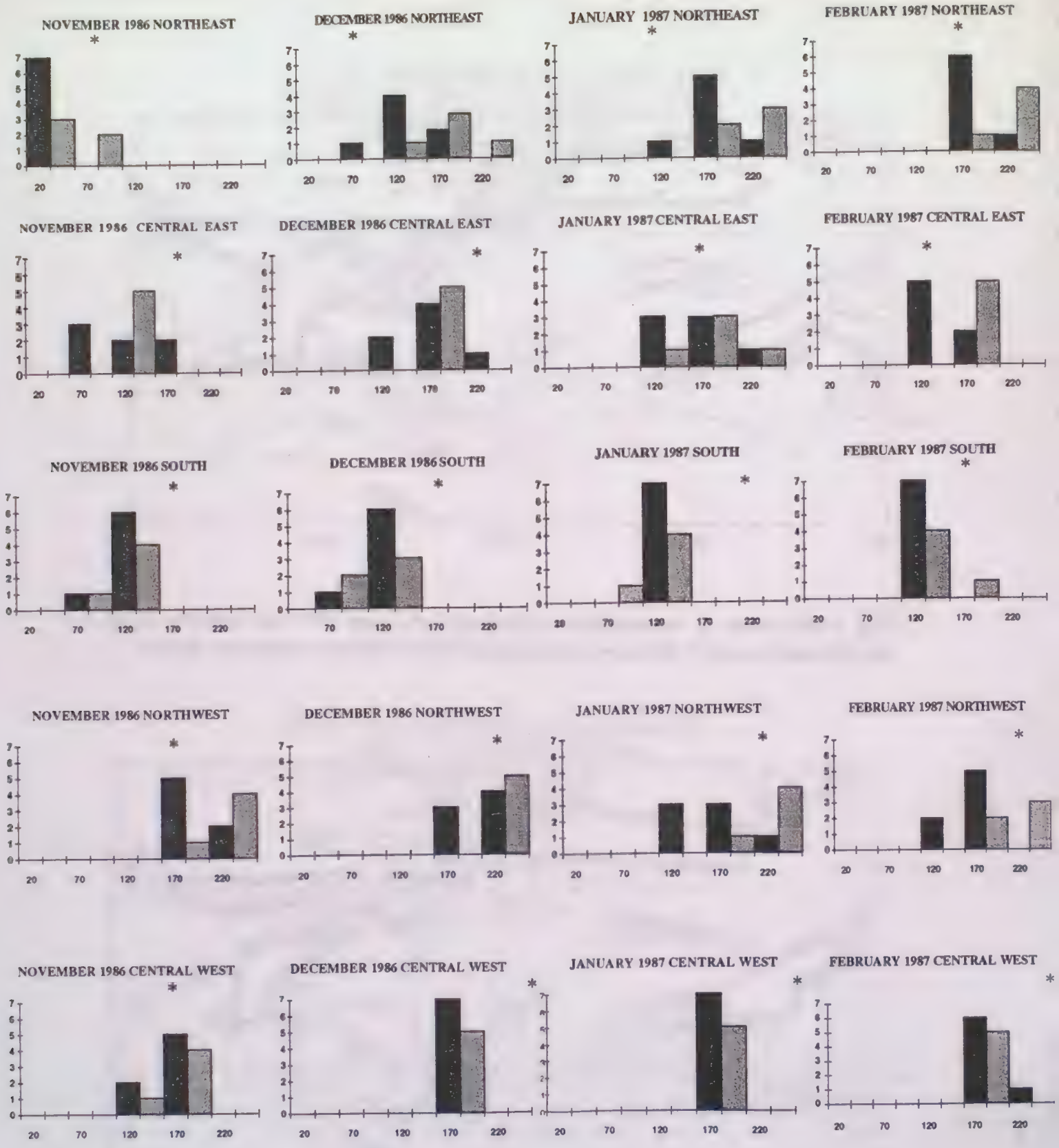


Fig. 3- Frequency distribution of convective rain. The dark shaded blocks are the results using observed SSTs (7 members) and the light blocks using climatological SSTs (5 members). Distributions for each SST type are offset. The star (*) indicates the observed precipitation value.

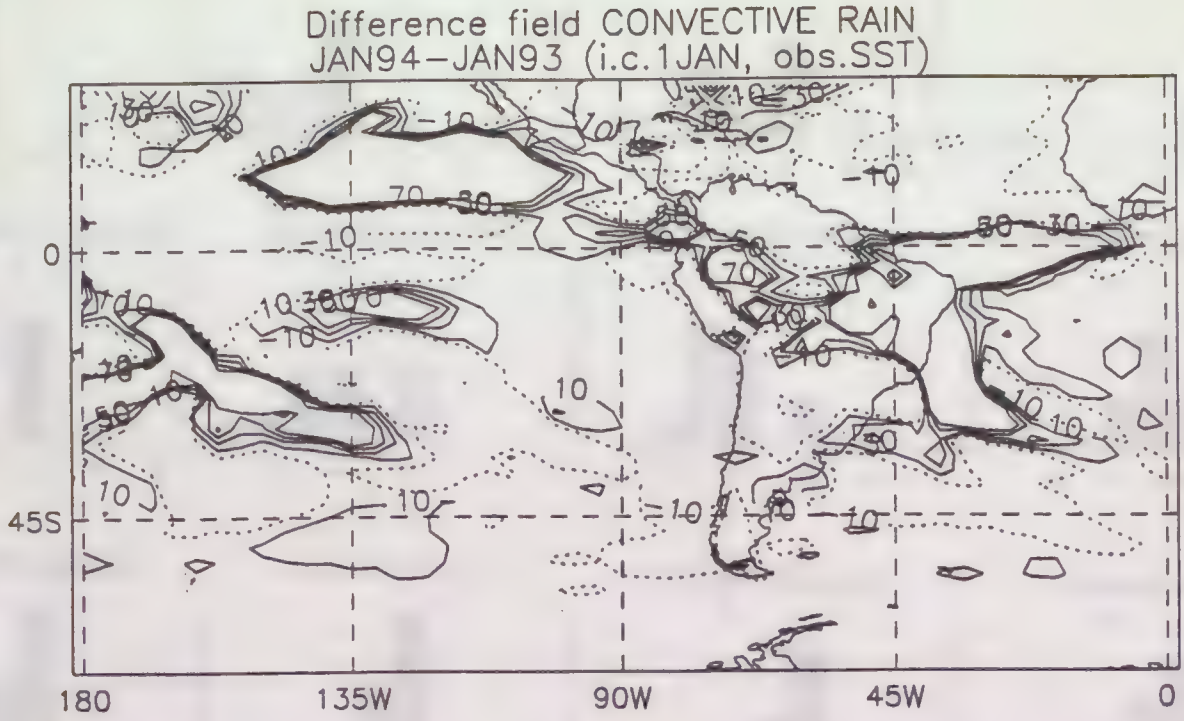


Fig. 4-Difference of convective rain between 1994 and 1993 for January, using initial conditions of 1 January and observed SSTs. Negative values are dotted.

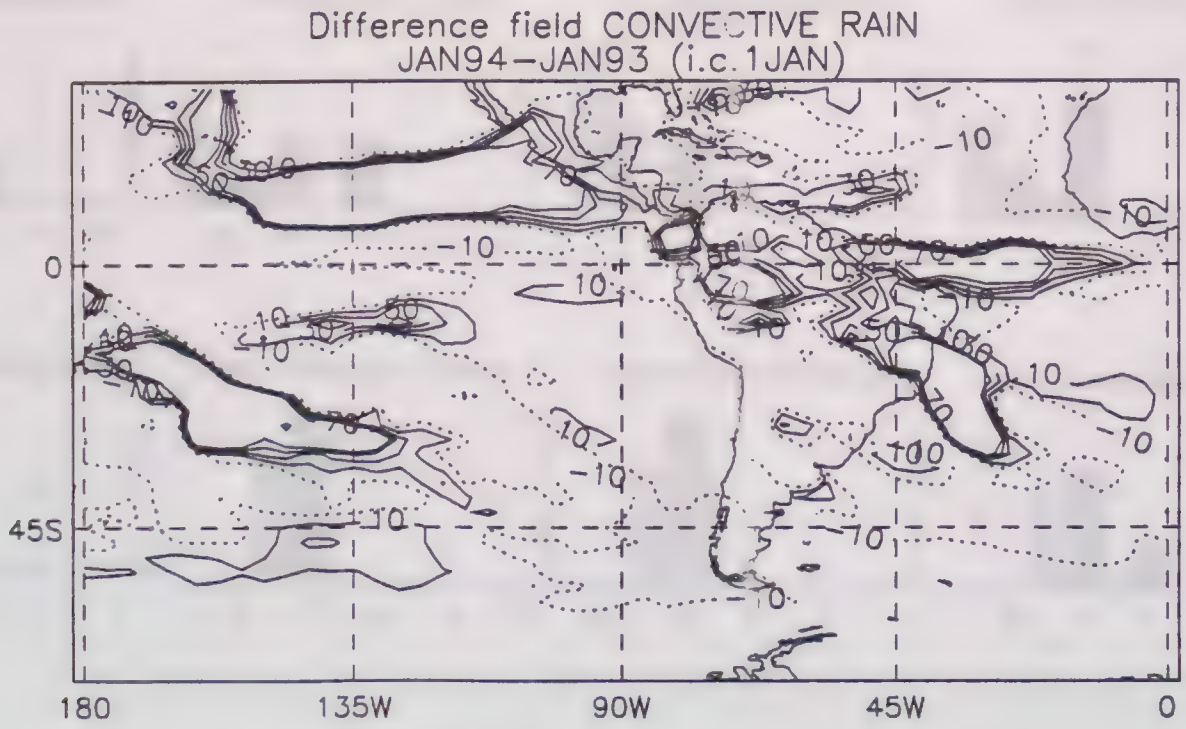


Fig. 5- Difference of convective rain between 1994 and 1993, for January, using initial conditions of 1 January and observed SSTs (1993) and persisted SST anomalies (1994). Negative values are dotted.

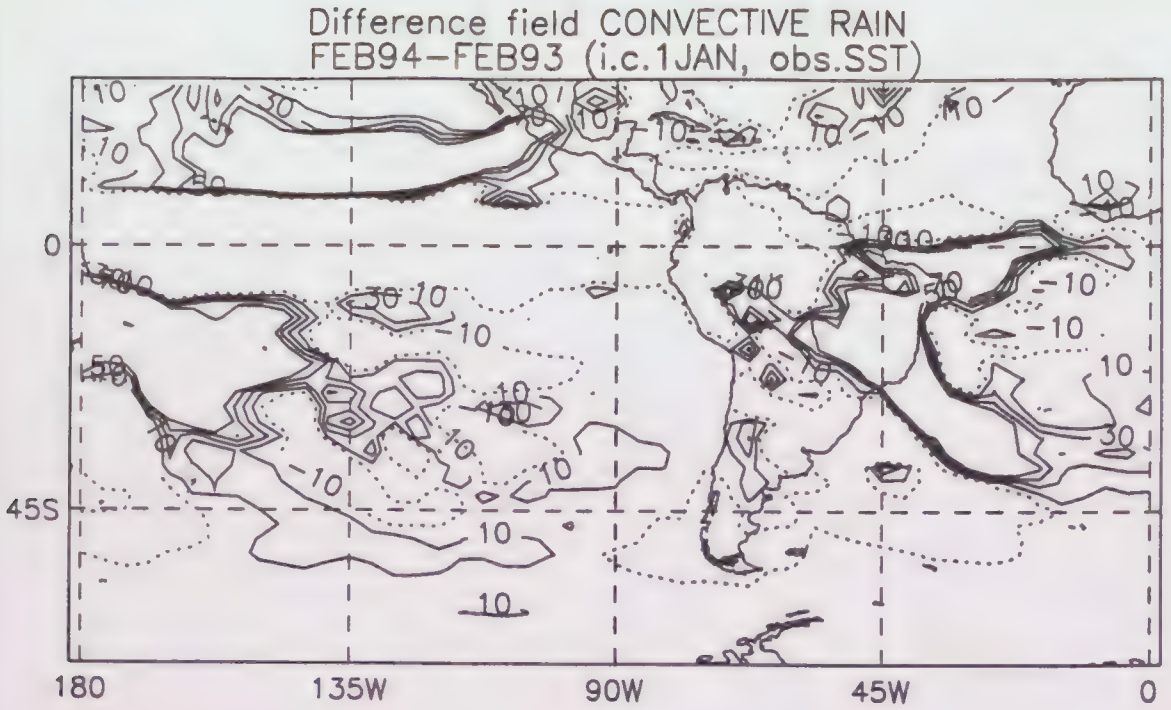


Fig. 6- As Fig. 4, but for February.

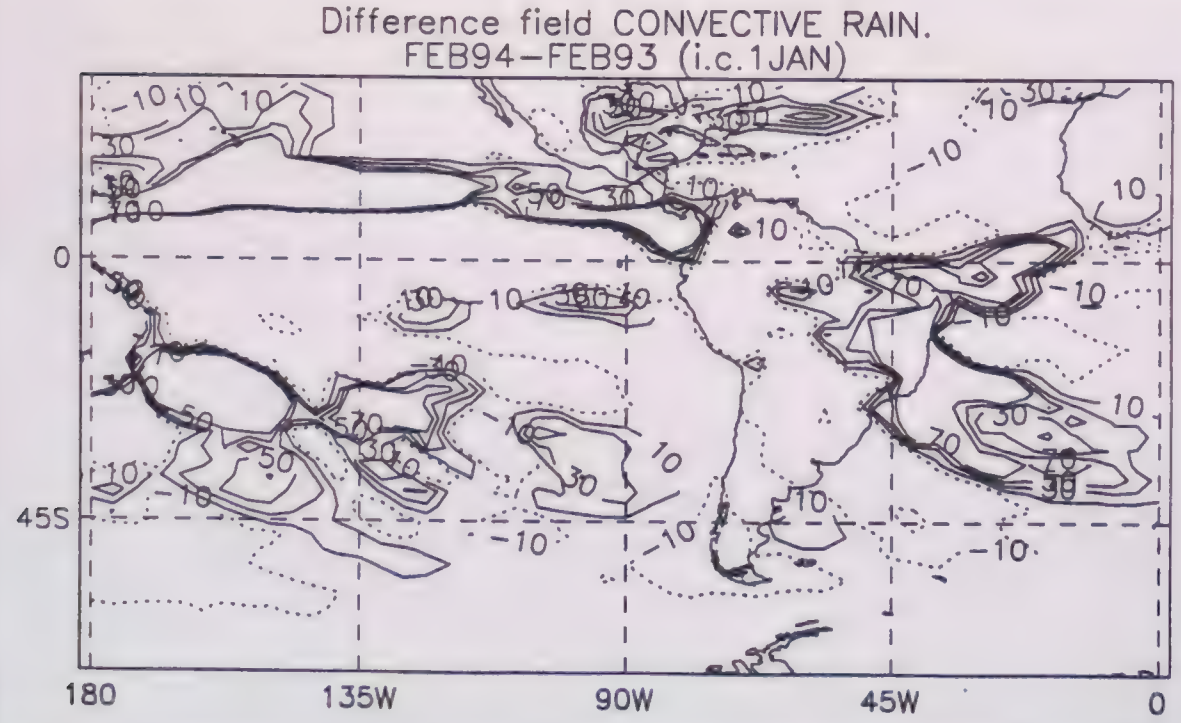


Fig. 7- As Fig. 5, but for February.

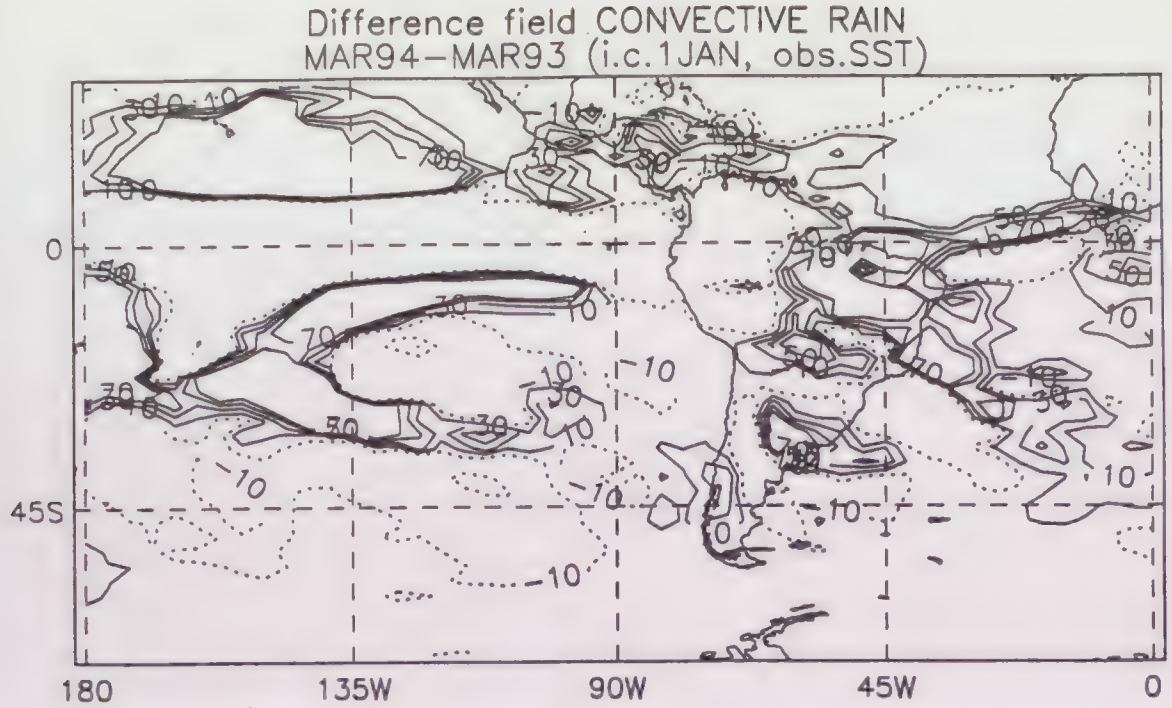


Fig. 8- As Fig.4, but for March

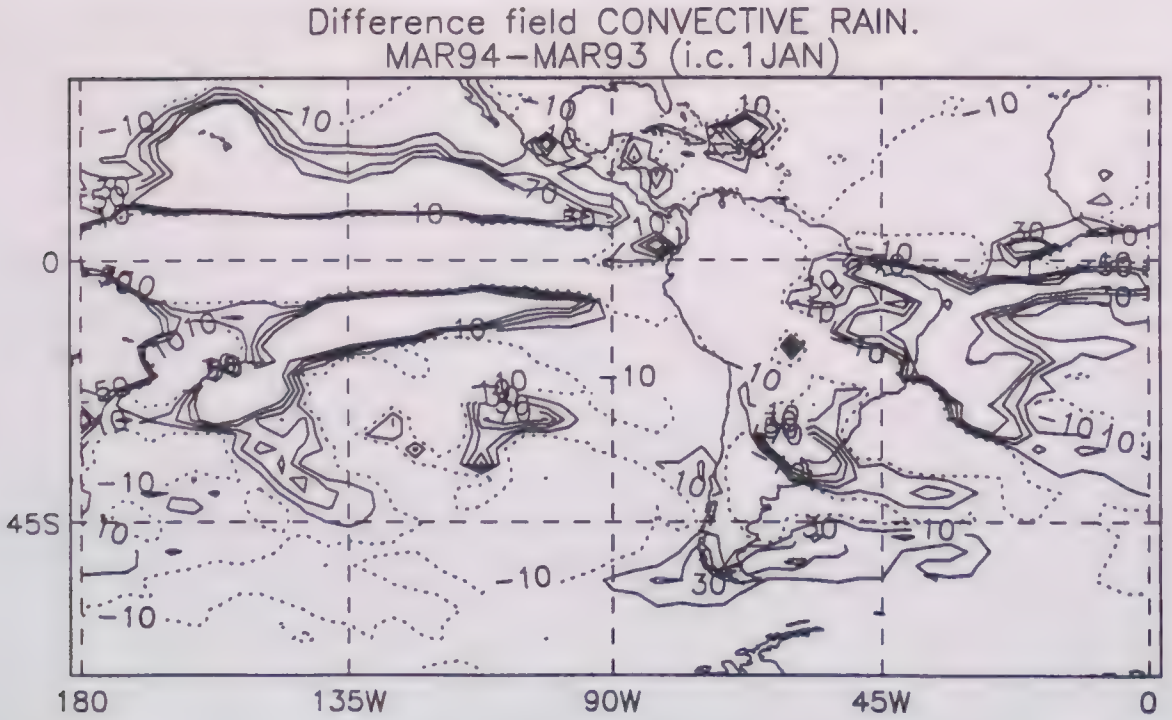


Fig. 9- As Fig. 5, but for March.

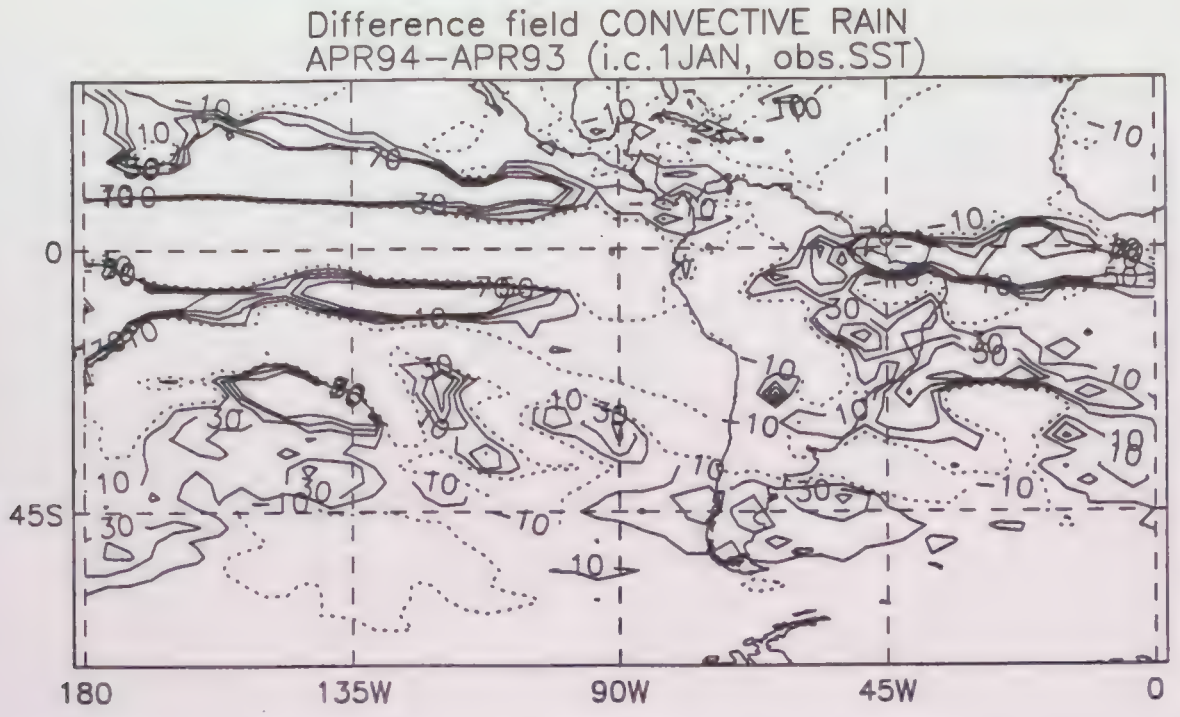


Fig. 10- As Fig. 4, but for April.

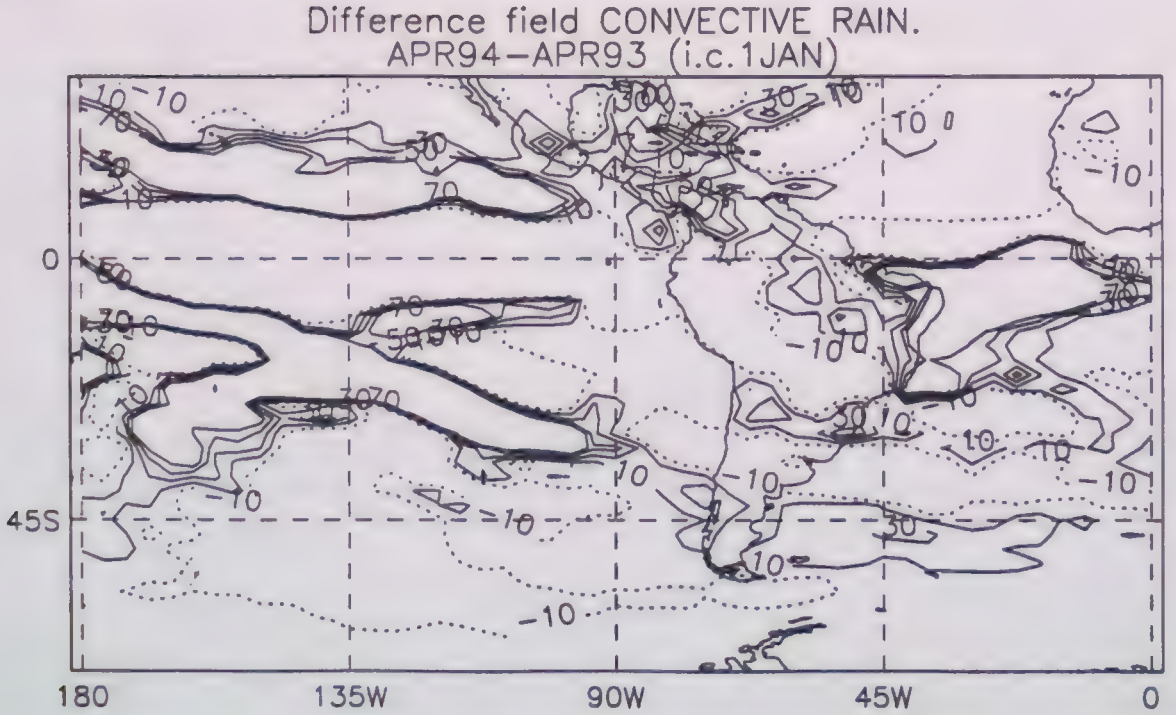


Fig. 11-As Fig. 5, but for April.

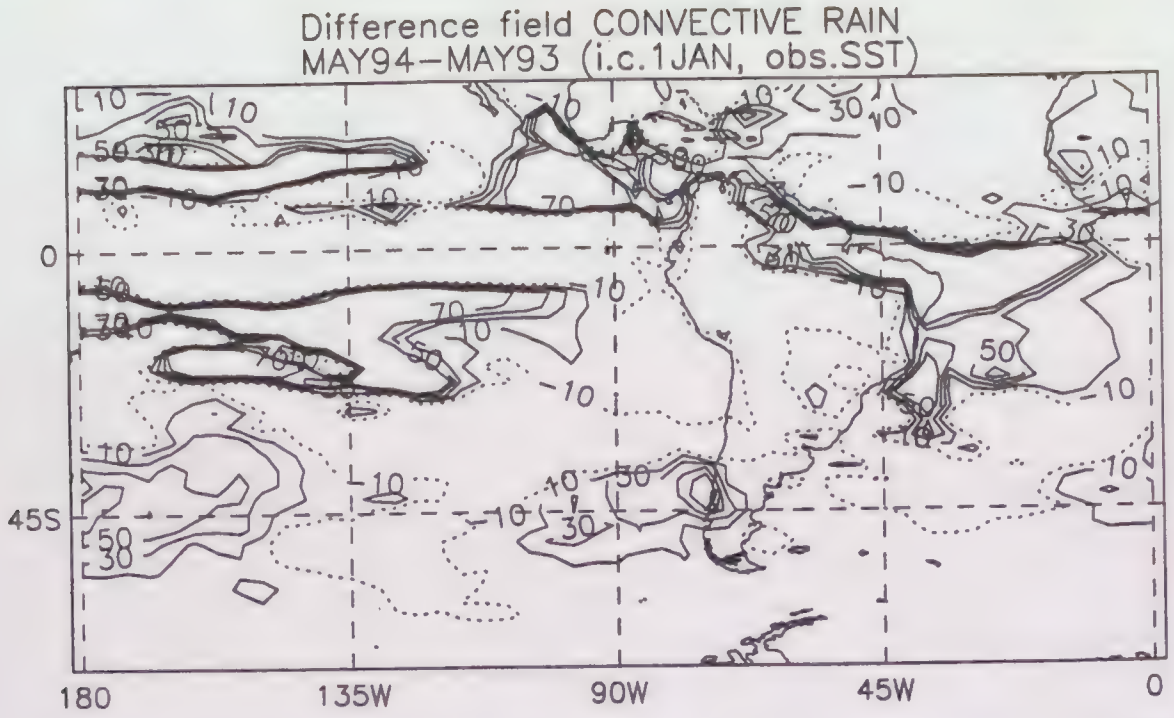


Fig. 12- As Fig. 4, but for May.

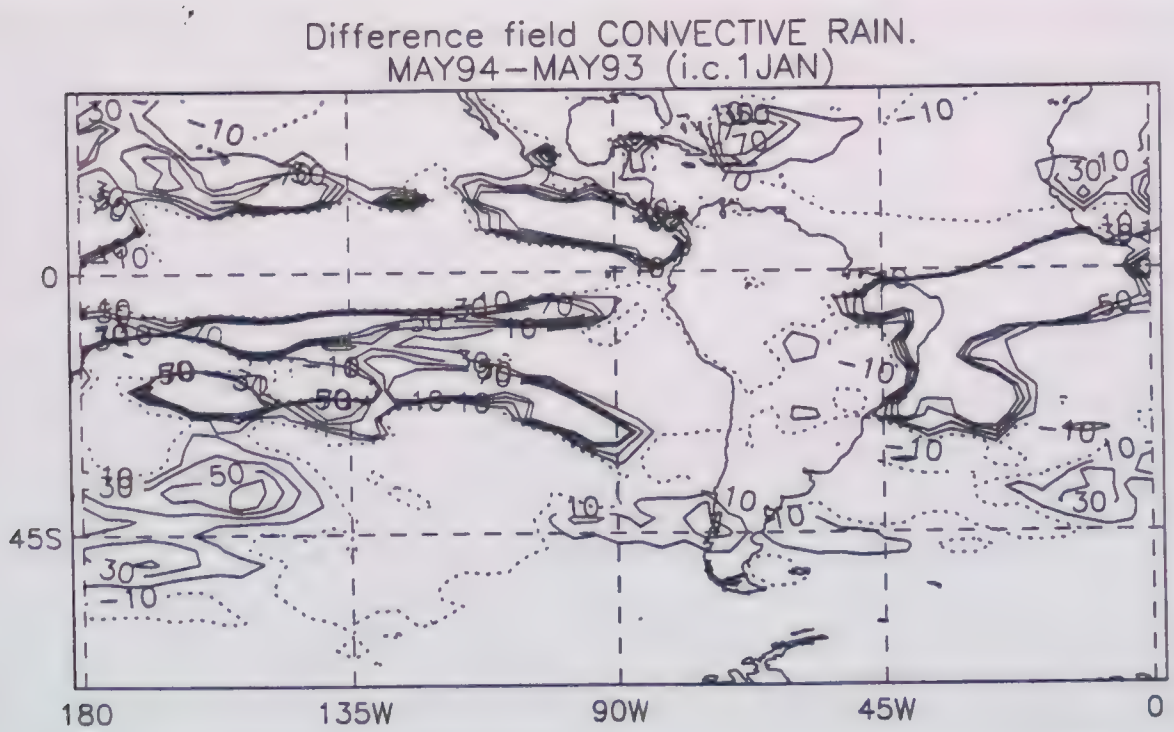


Fig. 13- As Fig. 5, but for May.

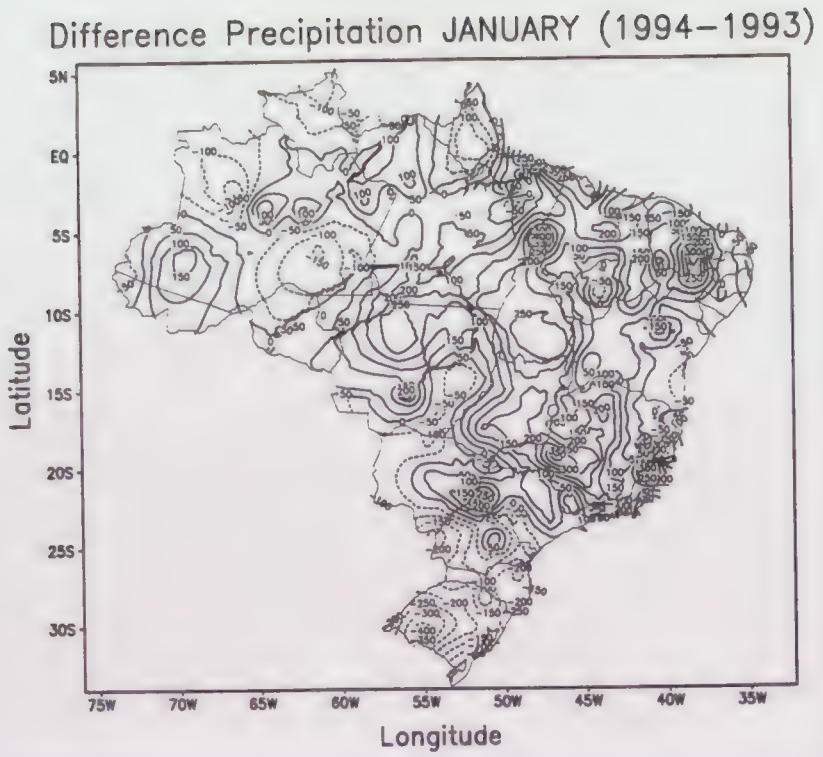


Fig. 14- Difference of Observed Precipitation in January, between 1994 and 1993. Negative values are dotted.

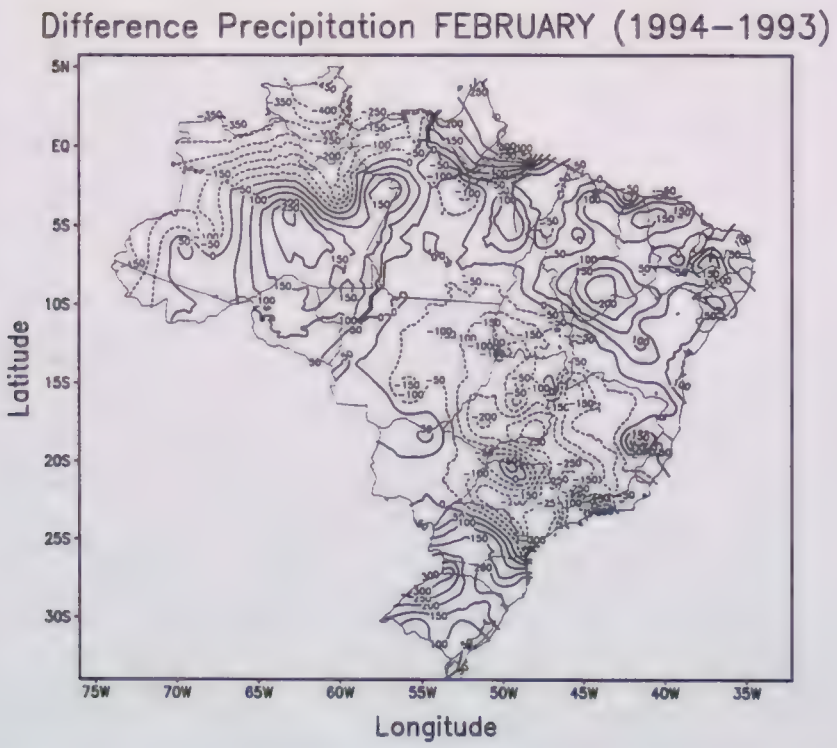


Fig. 15- As Fig. 14, but for February.

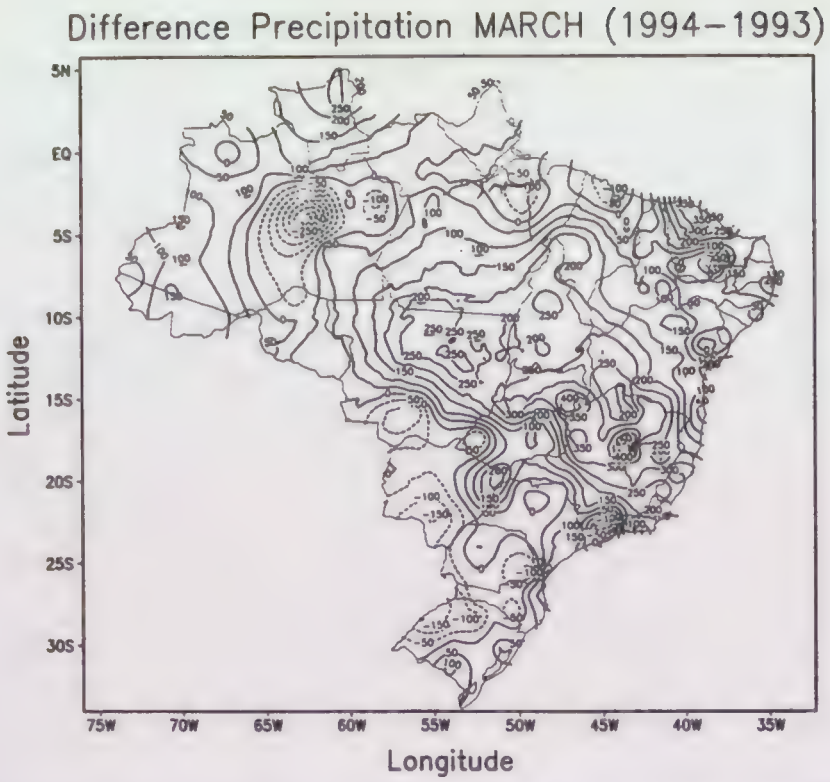


Fig. 16- As Fig. 14, but for March.

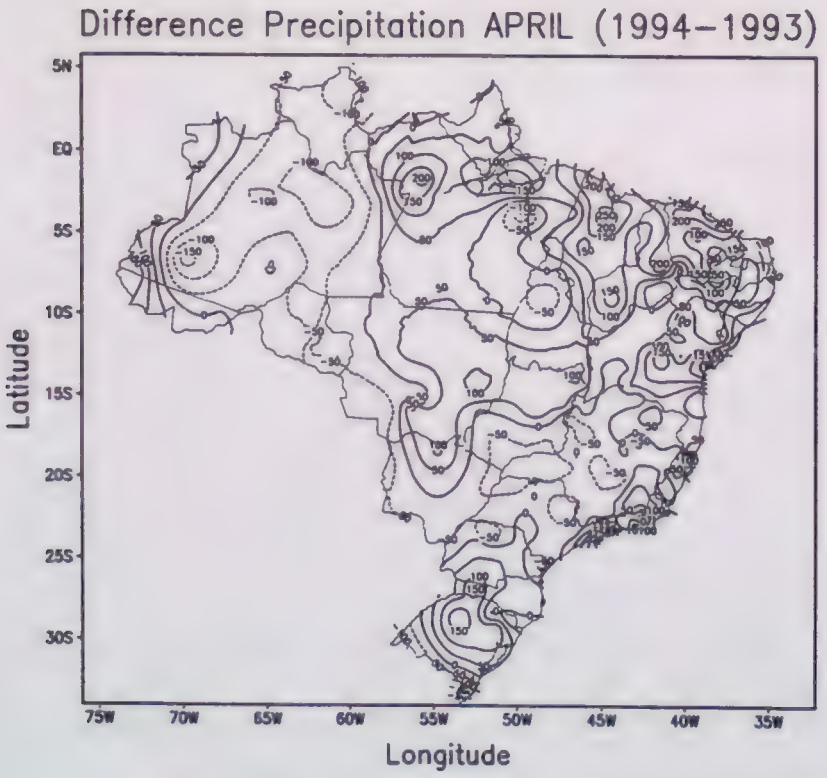


Fig. 17- As Fig. 14, but for April.

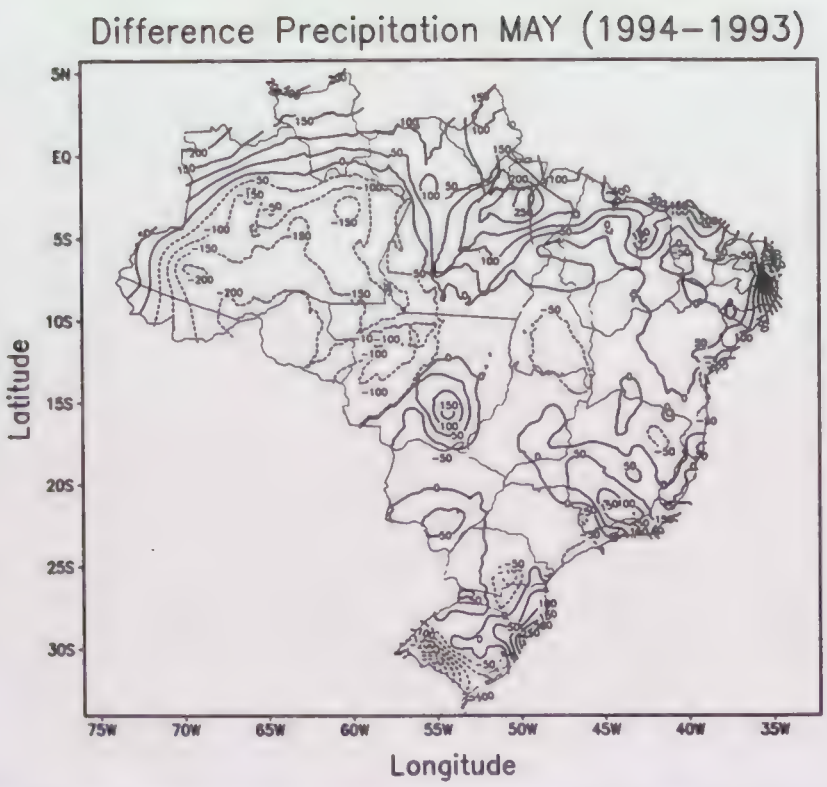
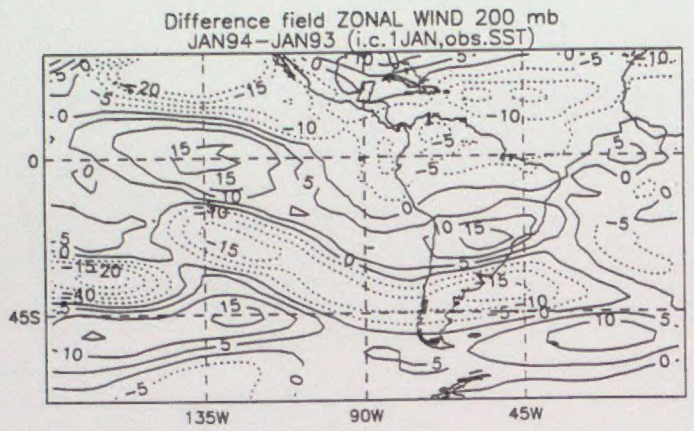


Fig. 18- As Fig. 14, but for May.



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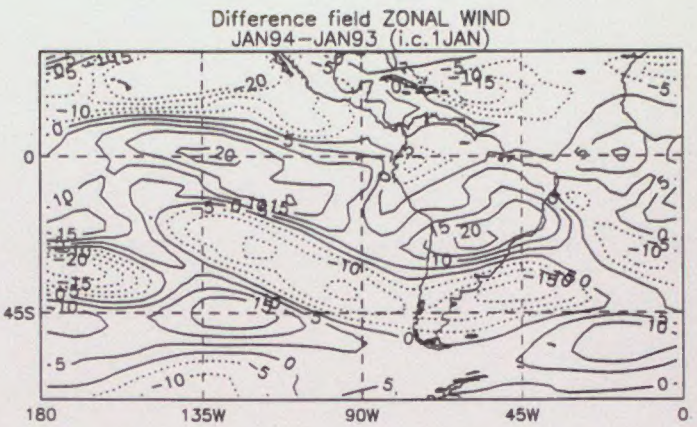
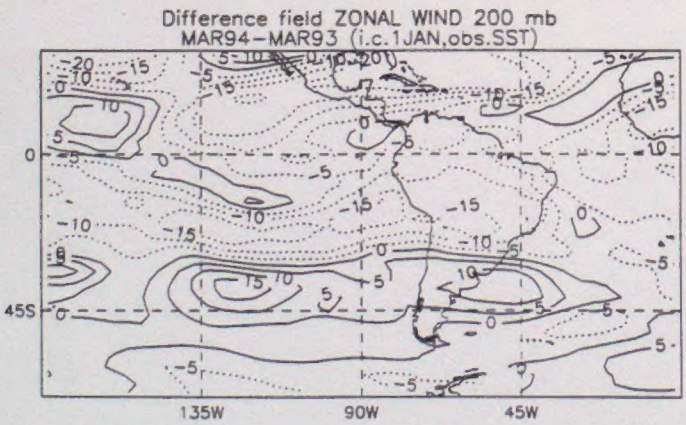


(b)



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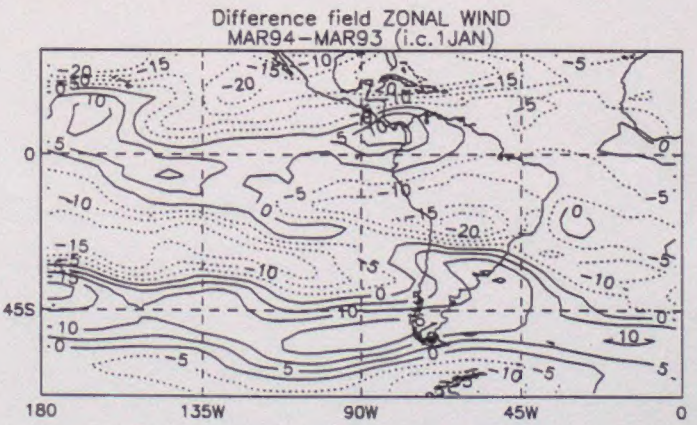
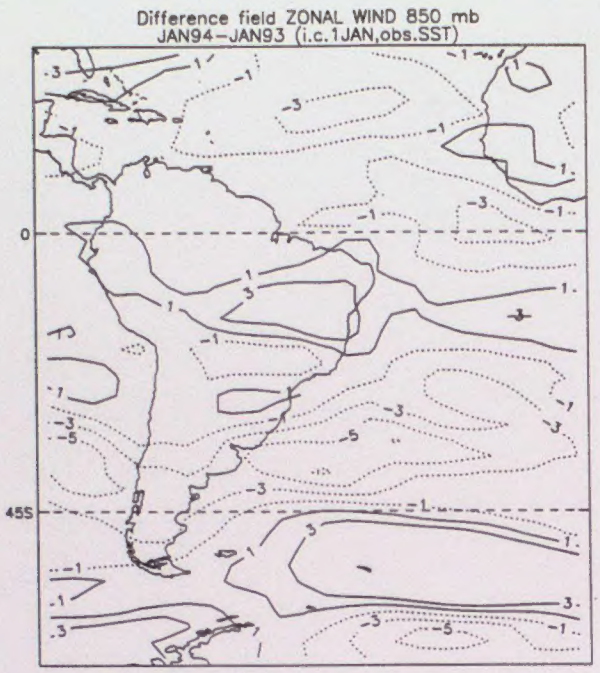


(d)

Fig. 19- Differences of zonal winds at 200 hPa between 1994 and 1993. a) January, using observed SSTs, b) January, using persisted December SST anomalies, c) March, using observed SSTs, d) March, using persisted December SST anomalies.



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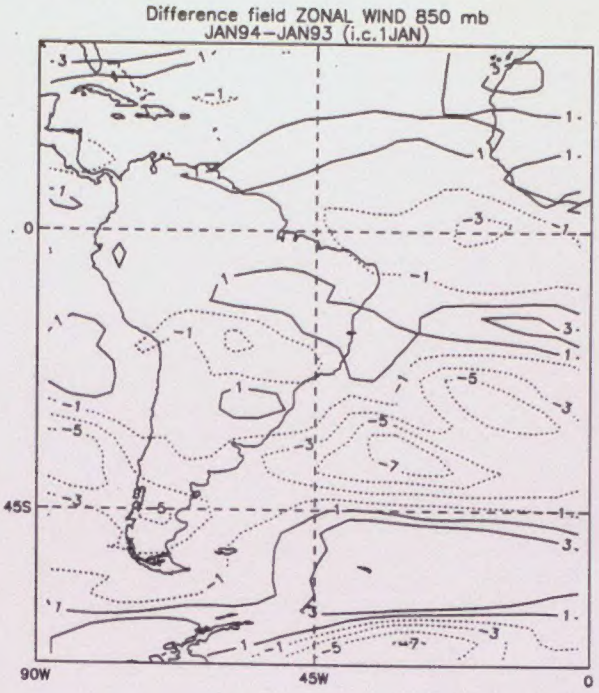
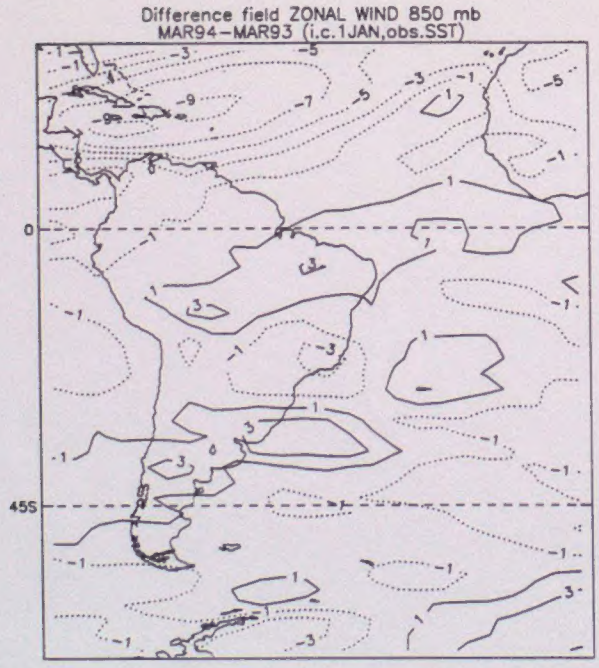
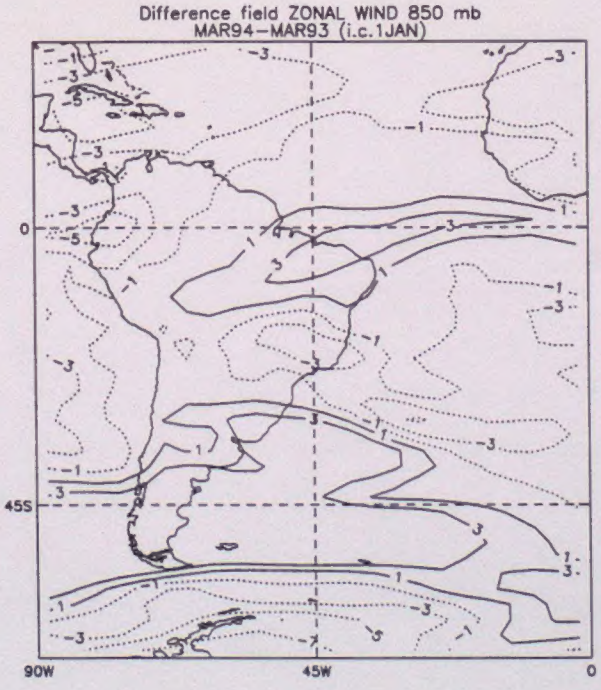


(b)

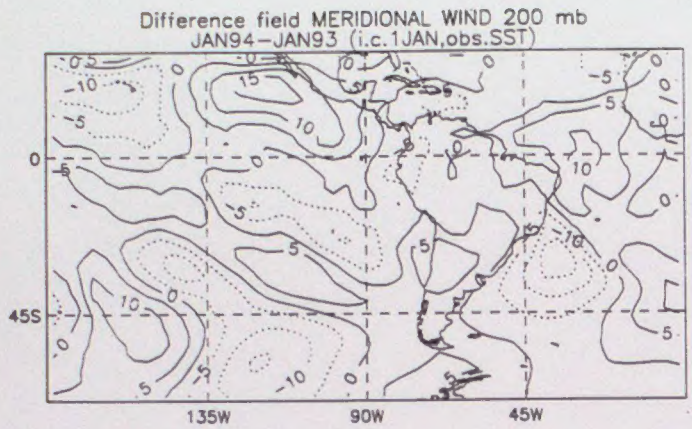


(c)

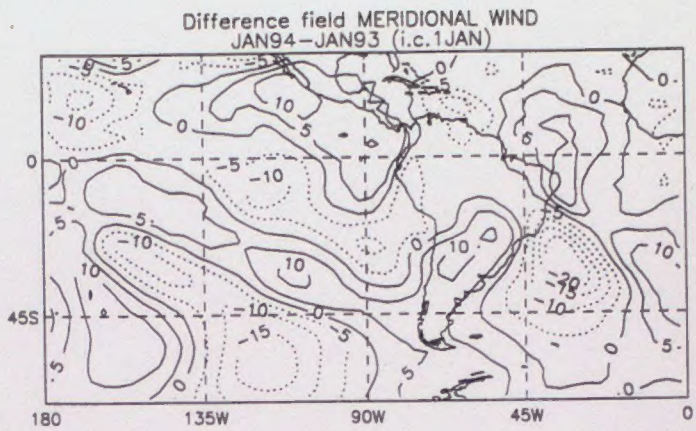


(d)

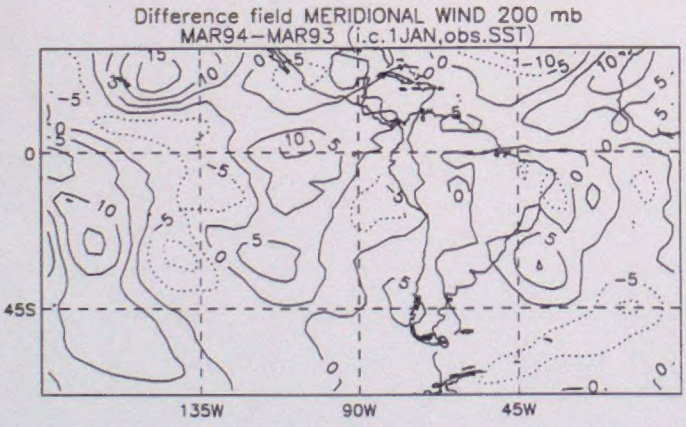
Fig. 20- As Fig.19, but at 850 hPa.



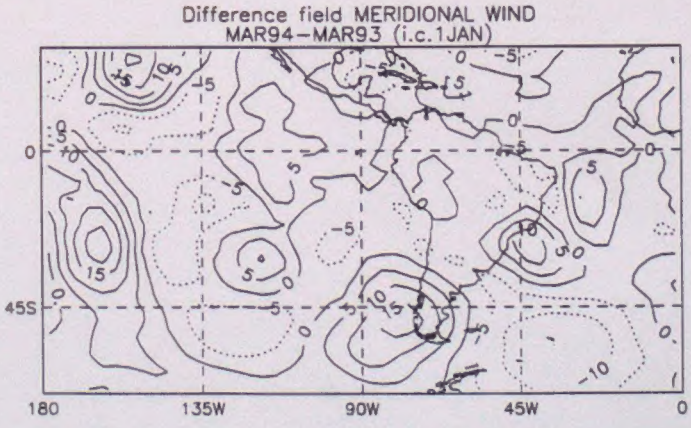
(a)



(b)



(c)



(d)

Fig. 21- Differences of meridional winds at 200 hPa between 1994 and 1993 . a) January, using observed SSTs, b) January, using persisted December SST anomalies, c) March, using observed SSTs, d) March, using persisted December SST anomalies.

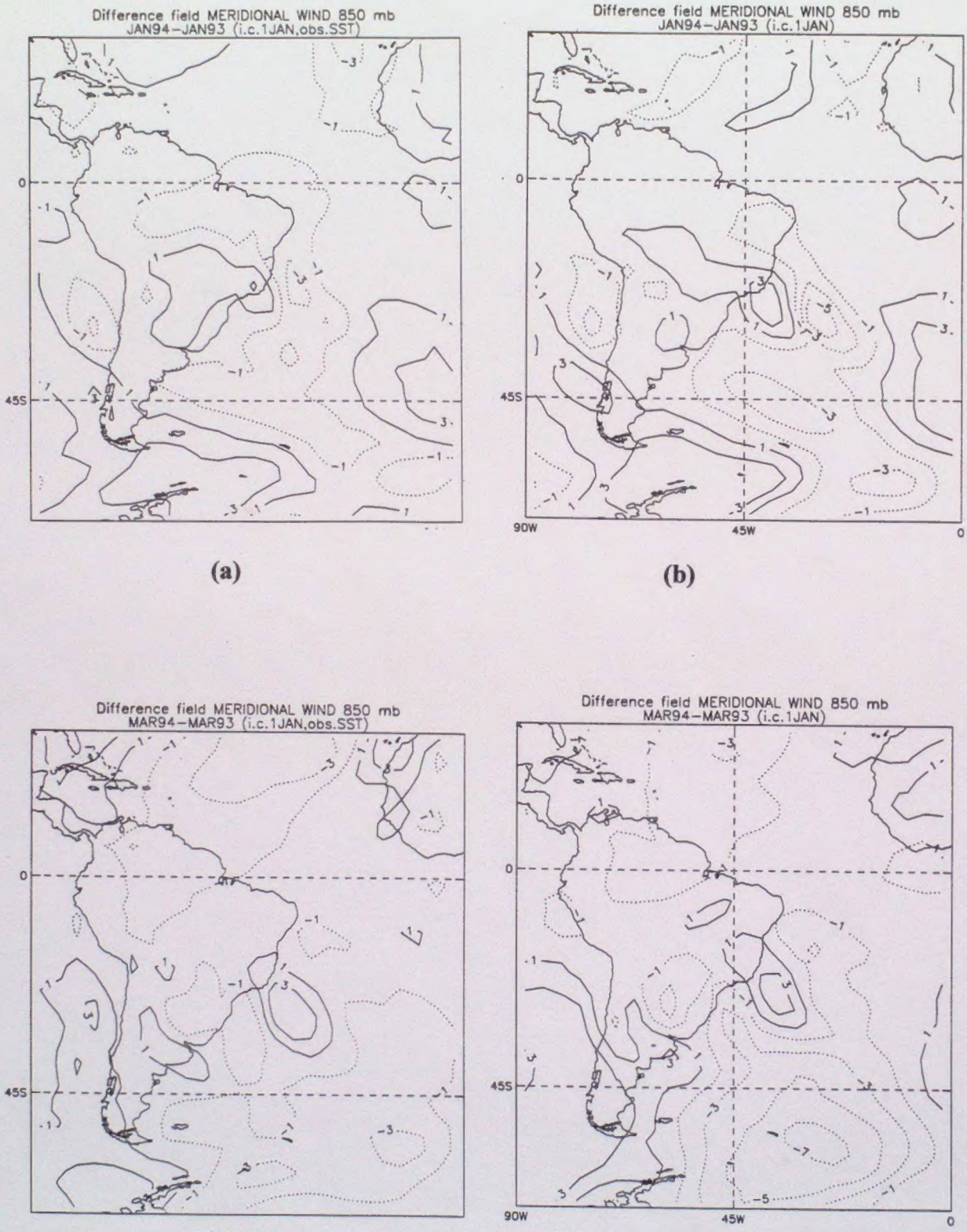


Fig. 22- As Fig. 21, but at 850 hPa.